Acid-Base Titration Curves

INSTRUCTOR RESOURCES

The CCLI Initiative

Learning Objectives

to understand the titration curves for the following solutions

- a weak acid: acetic acid, CH_3COOH.
- a strong acid: hydrochloric acid, HCl.
- an acidic commercial cleanser.
- a basic commercial cleanser.
- to use the titration curves to calculate the percent of the active ingredients in the commercial cleansers.
- to determine the K_a of a weak acid.

Procedure Overview

- after calibration of the pH electrode and determination of the flow rate for the automatic titration, a NaOH solution is standardized against HCl.
- a pH titration curve for acetic acid is obtained and its pK_a is determined.
- an unknown sample of Lysol is analyzed for its HCl content using the standardized NaOH.
- an unknown sample of Liquid Plumr is analyzed for its NaOH and NaOCl content using HCl of known molarity.

Name _____ Section _____ Date _____

ACID-BASE TITRATION CURVES

Report Sheet

Determination of flow rate

Equation for conversion from time to volume:

Titration of HCl

pH at equivalence point _____

volume of NaOH at equivalence point _____

concentration of HCl _____

volume of HCl _____

Titration of acetic acid

pH at equivalence point _____

volume of NaOH at equivalence point _____

volume at half-equivalence point _____

pH at half-equivalence point _____

Titration of Lysol

weight of beaker with Lysol _____

weight of empty beaker _____

mass of Lysol _____

pH at equivalence point _____

volume of NaOH at equivalence point _____

Titration of Liquid Plumr

weight of beaker with Liquid Plumr _____

weight of empty beaker _____

mass of Liquid Plumr _____

pH at first equivalence point _____

volume of HCl at first equivalence point _____

pH at second equivalence point _____

volume of HCl at second equivalence point _____

Name _____ Section _____ Date _____

ACID-BASE TITRATION CURVES

Report Sheet

Calculations

1. **Titration of HCl (Standardization of NaOH)**
   a. Determine the moles of HCl.

   b. Calculate the molarity of NaOH.

2. **Titration of acetic acid**
   a. Calculate the K_a for acetic acid.

3. **Titration of Lysol**
   a. Calculate the percent HCl in Lysol.

4. Titration of Liquid Plumr
   a. Calculate the percent NaOH in Liquid Plumr.

   b. Calculate the percent NaOCl in Liquid Plumr.

Name _____ Section _____ Date _____

ACID-BASE TITRATION CURVES

Questions/Problems

1. Calculate the pH of a solution in which the concentration of the hydronium ion equals 2.0×10^{-4} M.

2. If the pH at the half-equivalence point for a titration of a weak acid with a strong base is 4.60, determine the value of the K_a for the weak acid.

3. When a 0.5725 g sample of Lysol was titrated with 0.100 M NaOH, an endpoint was obtained at 15.00 ml. Calculate the percent (by weight) of hydrochloric acid in the Lysol sample.

4. When a 3.529 g sample of Liquid Plumr was titrated with 0.100 M HCl, two endpoints were obtained. The first endpoint occurred at 15.00 ml, the second at 42.00 ml. Calculate the percentages of both NaOH and NaOCl in Liquid Plumr.

5. If you did a "manual" titration, compare the graphically determined equivalence point and the indicator determined end point. If you did a "timed" titration, the indicator-determined end point **MAY** have passed too quickly to get meaningful data, but try to make a comparison as best you can.

ACID-BASE TITRATION CURVES

Suggested Answers to Questions/Problems

1. (A) Calculate the pH of a solution in which the concentration of the hydronium ion equals 2.0×10^{-4} M.

pH = log[H_3O^+] = log(2.0×10^{-4})

pH = 3.70

(b) If the pH at the half-equivalence point for a titration of a weak acid with a strong base is 4.60, determine the value of the Ka for the weak acid.

pK_a = pH @ ½ equivalence point

Ka = $10^{-4.60}$ = 2.5×10^{-5}

2. When a 0.5725 g sample of Lysol was titrated with 0.100 M NaOH, an endpoint was obtained at 15.00 ml. Calculate the percent (by weight) of hydrochloric acid in the Lysol sample.

$$\%HCl = \frac{(15 \text{ ml HCl soln})(0.100 \text{ mmol NaOH})(36.5 \text{ g})(1 \text{ mol})(100)}{(0.5725 \text{ g sample})(1.00 \text{ ml soln})(1 \text{ mol})(10^3 \text{ mmol})(100)} = 9.56\ \%$$

3. When a 3.529 g sample of Liquid Plumr was titrated with 0.100 M HCl, two endpoints were obtained. The first endpoint occurred at 15.00 ml, the second at 42.00 ml. Calculate the percentages of both NaOH and NaOCl in Liquid Plumr.

1st equivalence point = HCl reacting with NaOH = 15.00 ml

2nd eq. point = HCl reacting with NaOCl = 42.00 ml – 15.00 ml = 27.00 ml

4. If you did a "manual" titration, compare the graphically determined equivalence point and the indicator determined end point. If you did a "timed" titration, the indicator-determined end point **MAY** have passed too quickly to get meaningful data, but try to make a comparison as best you can.

The indicator determined end point is noticeable before the equivalence point. A faint pink color begins to appear before the equivalence point is reached.

ACID-BASE TITRATION CURVES

Tips and Traps

1. Lysol and Liquid Plumr should be dispensed in a fume hood, using an automatic dispenser, if possible.

2. Students should determine the flow rate three times and average the result. Flow rate should be determined for each titration separately.

ACID-BASE TITRATION CURVES

Sample Data

Determination of flow rate

Equation for conversion from time to volume:

Titration of HCl

pH at equivalence point	7.0	
volume of NaOH at equivalence point	20.6	ml
concentration of HCl	0.100	M
volume of HCl	25.00	ml

Titration of acetic acid

pH at equivalence point	8.4	
volume of NaOH at equivalence point	21.50	ml
volume at half-equivalence point	10.75	ml
pH at half-equivalence point	4.7	

Titration of Lysol

weight of beaker with Lysol	67.5794	g
weight of empty beaker	65.6321	g
mass of Lysol	1.9473	g
pH at equivalence point	7.0	
volume of NaOH at equivalence point	40.56	ml

ACID-BASE TITRATION CURVES

Sample Data (page 2)

Titration of Liquid Plumr

weight of beaker with Liquid Plumr	67.8074	g
weight of empty beaker	65.6321	g
mass of Liquid Plumr	2.1753	g
pH at first equivalence point	9.2	
volume of HCl at first equivalence point	9.20	ml
pH at second equivalence point	4.7	
volume of HCl at second equivalence point	13.6	ml

Calculations

Titration of HCl (Standardization of NaOH)

1. Determine the moles of HCl.

$$0.100\ M \times 0.02500\ L = 0.00250\ mol$$

2. Calculate the molarity of NaOH.

at equivalence point: mol NaOH = mol HCl

$$[NaOH] = \frac{0.00250\ mol}{0.0206\ L} = 0.121\ M$$

Titration of acetic acid

1. Calculate the K_a for acetic acid.

$$pK_a = pH_{1/2} = 4.7 \qquad K_a = 10^{-4.7} = 2.0 \times 10^{-5}$$

Titration of Lysol

1. Calculate the percent HCl in Lysol.

$$\%HCl = \frac{(40.56\ ml\ NaOH)(0.121\ mmol\ NaOH)(36.5\ g)(1\ mol)(100)}{(1.9743\ g\ sample)(1.00\ ml\ soln)\ (1\ mol)\ (10^3\ mmol)(100)} = 9.23\ \%$$

ACID-BASE TITRATION CURVES

Sample Data (page 3)

Titration of Liquid Plumr

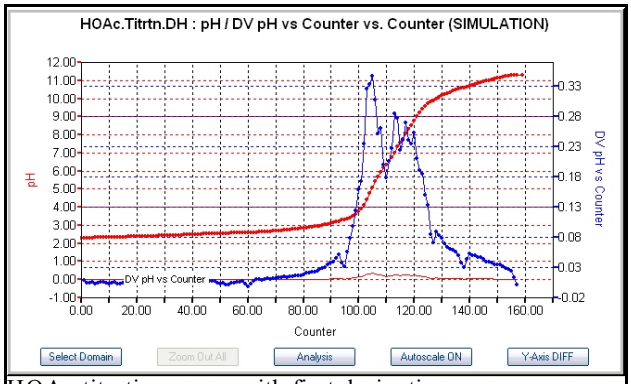
1. Calculate the percent NaOH in Liquid Plumr.

$$\%NaOH = \frac{(9.20\ ml\ HCl)(0.100\ mmol\ HCl)(40.0\ g)(1\ mol)(100)}{(2.1753\ g\ sample)(1.00\ ml\ soln)(1\ mol)(10^3\ mmol)(100)} = 1.69\ \%$$

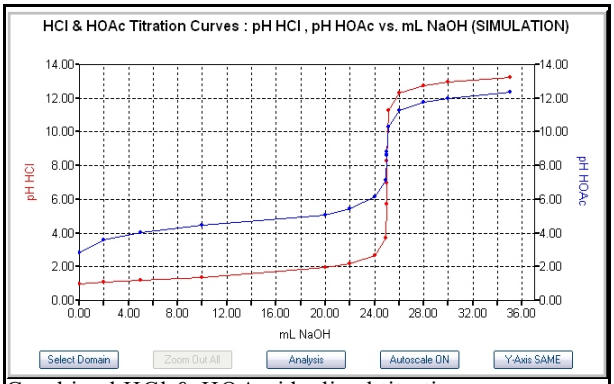
2. Calculate the percent NaOCl in Liquid Plumr.

$$\%NaOCl = \frac{((13.6-9.2)\ ml\ HCl)(0.100\ mmol\ NaOH)(74.4\ g)(1\ mol)(100)}{(2.1753\ g\ sample)(1.00\ ml\ soln)(1\ mol)(10^3\ mmol)(100)} = 1.51\ \%$$

Sample Titration Curves



HOAc titration curve with first derivative.



Combined HCl & HOAc idealized titration curves

ACID-BASE TITRATION CURVES

Laboratory Preparation (per student station)

Equipment

- two 250-ml beakers
- 150-ml beaker
- 50-ml buret
- buret clamp
- 25-ml graduated cylinder
- 10-ml graduated cylinder
- glass stirring rod
- glass funnel (short stem)
- pH electrodes + stands w/ clamp
- timer

Supplies

- towel

Chemicals

Exact quantities needed are listed below. A minimum 50% excess is recommended.

- 2.5 *M* NaOH, 10 ml
- 0.1 *M* HCl, 50 ml
- 0.1 *M* CH_3COOH, 25 ml
- pH 4, 7 and 10 buffer solutions, 15 ml each, reusable
- Lysol, 2 ml
- Liquid Plumr, 2 ml

Safety and Disposal

- Lysol: handle with care - strongly acidic. Can be flushed down drain with lots of water
- Liquid Plumr: handle with care - strongly basic. Can be flushed down drain with lots of water